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Understanding Environmental Models in Their Legal and Regulatory Context

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Abstract

Environmental models are playing an increasingly important role in most jurisdictions and giving rise to disputes. Despite this fact, lawyers and policy-makers have overlooked models and not engaged critically with them. This is a problematic state of affairs. Modelling is a semi-autonomous, interdisciplinary activity concerned with developing representations of systems and is used to evaluate regulatory behaviour to ensure it is legitimate. Models are thus relevant to lawyers and policy-makers but need to be engaged with critically due to technical, institutional, interdisciplinary and evaluative complexities in their operation. Lawyers and policy-makers must thus think more carefully about models and in doing so reflect on the nature of their own disciplines and fields.

Keywords: Models, environmental regulation, science and law, administrative decision-making

This article is about the important and complex role that models play in environmental regulation. While models tend to be perceived as inanimate, technical inputs for environmental decision-making, in truth models are contingent on numerous policy-relevant assumptions and framing decisions

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for which policy-makers should be centrally involved. In this piece, we discuss not only the key role that lawyers and policy-makers should play in the development and use of models, but highlight for these non-scientific groups the inner workings of models so that they can better appreciate their contributions. Despite our focus on the inner working of models, however, no specialist expertise in modelling is required of our readers. Nor will we dazzle you with numbers, bamboozle you with language, or overwhelm you with diagrams. Our purpose is simultaneously more modest and more challenging. It is more modest because our aim is to provide an overarching conceptual explanation of why environmental models are relevant to lawyers and policy-makers, and why, because they are relevant, lawyers and policy-makers must critically engage with models. Achieving this objective is more challenging, because neither the relevance nor the need for critical engagement is self-evident to lawyers and policy-makers.

The structure of this article is as follows. First, we briefly review the increasing role that models play in environmental decision-making. Models are playing three different roles: as policy catalysts; as devices for fleshing out institutional mandates; and as regulatory strategies. Moreover, models are increasingly the focus of policy and legal disputes. Despite the prevalence of models and disputes over them, lawyers and policy-makers have not understood them to be in their domain due to their technical and administrative nature. In the second section, we show that while models may not be within the conventional expertise of lawyers and policy-makers, they are relevant to what they do. This is because modelling is a semi-autonomous, interdisciplinary activity concerned with developing representations of systems which provide the rationale and basis of much regulatory behaviour. Or to put the matter another way, models govern what is understood as legitimate regulatory action.

In the third section, we show how lawyers and policy-makers must not only appreciate the relevance of models to what they do, but also the complexity of models. We examine four particular types of complexity: technical, institutional, interdisciplinary and evaluative. In the final section, we argue there are three important conclusions that can be drawn from our analysis. Models cannot be ignored by lawyers and policy-makers. Models need to be treated with care by these groups and in thinking about models there is also a need to reflect on what is understood to be the scope of law and policy.

Five important points should be made before starting our analysis. First, this article is not an article arguing for or against the validity of models. Our starting point is that models are an inherent feature of environmental regulation. Second, the focus of this article is upon identifying the generic features of models which make them relevant and challenging for lawyers and policy-makers to think about. Third, and related to this point, while the importance

of regulatory and legal culture is central to our argument,[1] in this article we deliberately discuss a number of different jurisdictions in passing as we want to highlight that models are an omnipresent feature of nearly all environmental regulation regimes. Fourth, in referring to lawyers and policy-makers we define these two groups broadly to include all those involved in environmental regulation decision-making and its review including those who wish to support or challenge regulatory decisions. Finally, we do not see our critical agenda as an exhaustive analysis of the role of models in environmental regulation. Much more could and should be said about models.[2]

1. The Prevalence of Models in Environmental Regulation

An obvious starting point in an article about models is to define what a model is. The National Research Council (NRC), a prestigious science policy-making body in the United States, organized a panel that has defined a model as:

> a simplification of reality that is constructed to gain insights into select attributes of a particular physical, biological, economic, or social system. They can be of many different forms.[3]

This definition is bland but it is a good starting point for the simple fact that most readers will recognise something familiar in such a definition. This is because, most environmental lawyers and policy-makers will have stumbled across such 'simplifications of reality' in their work and found themselves needing to think about a particular model whether it be a model concerning climate change, groundwater contamination, air quality, economic impact or something else. These models may be large scale and very complex or small and relatively simple. Likewise, lawyers and policy-makers may interact with them directly or may find themselves interacting with decisions based on a model or based on particular interpretations of a model.

Our focus in this article is upon why lawyers and policy-makers find themselves engaging with models, and what they should keep in mind when they do. Yet before we can discuss these two issues, we must provide a brief sketch of the current regulatory landscape—a landscape in which models and disputes over them are increasingly prevalent but despite that fact, lawyers and policy-makers do not see models as relevant to what they do.

1 E Fisher, *Risk Regulation and Administrative Constitutionalism* (Hart Publishing, Oxford 2007).
2 W Wagner and others, 'Misunderstanding Models in Environmental and Public Health Regulation' (2010) 18 New York University Environmental Law Journal 101.
3 National Research Council (NRC), *Models in Environmental Regulatory Decision Making* (National Academies Press, Washington DC 2007) 31.

1.1 The Prevalence of Models in Environmental Regulation

Models are now omnipresent in environmental regulation and they are playing many diverse roles in both law and policy in different legal cultures.[4] It is thus impossible in one article to either collate or even summarise the use of models in environmental law and we do not begin to attempt this. What is useful to do, is to highlight the different functional roles that models are performing in environmental regulation. Three large grouping of functions can be identified.

First, there are *policy-catalyst* models which play a role in informing policy in circumstances where no well established regime for regulatory action exists. The use of models in early climate change policy is the most obvious example here.[5] Thus, for example, the Intergovernmental Panel on Climate Change First Report was the foundation for the United Nations Framework Convention on Climate Change.[6] These models are thus establishing the premises for future state action where no such premises existed before. With that said, by acting as a foundation for new regimes they are then invariably incorporated into those regimes.[7] Moreover, these models are often relied upon in decision-making, the formulation of new laws[8] and legal disputes.[9]

Second, there are those models that have as their purpose the fleshing out of a discretionary legislative mandate by establishing the premises and rationale for particular action within a regulatory regime.[10] This very large group of models are our primary focus and are best described as *institutional mandate* models in that their primary function is to apply the institutional mandate of a regulatory institution to the issues that that institution is dealing with.

4 For examples in US environmental law, see <http://www.epa.gov/epahome/models.htm> accessed 16 June 2010 and NRC, ibid 47–8.

5 S Jasanoff and B Wynne, 'Science and Decision Making' in S Rayner and E Malone (eds), *Human Choice and Climate Change – Volume One* (Pacific Northwest National Laboratory, Battelle Press 1998); D Farber, 'Modeling Climate Change and Its Impacts: Law, Policy, and Science' (2008) 86 Texas Law Review 1655.

6 Intergovernmental Panel on Climate Change, *Intergovernmental Panel on Climate Change – First Assessment Report* (World Meteorological Organization/UNEP, Geneva 1990).

7 Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* (IPCC, Geneva 2007).

8 Council Directive (EC) 2008/101 of the European Parliament and of the Council of 19 November 2008 amending Council Directive (EC) 2003/87 so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community [2009] OJ L8/3.

9 The IPCC reports have been touched upon in numerous legal cases see *Walker v Minister for Planning* [2007] NSWLEC 741, [122]–[128]; *Xstrata Coal Queensland Pty Ltd v Queensland Conservation Council Inc* [2007] QLRT 33; Case C-440/05 *Commission v Council* [2008] 1 CMLR 22, [93] per AG Mazak; *Massachusetts v Environmental Protection Agency* (2007) 549 US 497, 508; *Small Hydro Power Developers' Association, v Transmission Corporation of AP Ltd* Appellate Tribunal for Electricity for New Delhi, MANU/ET/0033/2008. See also very indirectly *Dimmock v Secretary of State for Education & Skills* [2007] EWHC 2288 (Admin).

10 K J Holmes and others, 'Regulatory Models and the Environment: Practice, Pitfalls and Prospects' (2009) 29 Risk Analysis 159, 162. For a list of US examples see <http://cfpub.epa.gov/crem/knowledge.base/knowbase.cfm> accessed 14 June 2010.

The basis of that mandate is usually outlined in legislation but how that mandate is interpreted will depend on the prevailing legal and institutional culture.[11]

An important point to appreciate here is that the institution operating and utilising a model is nearly always administrative. That is, it is a non-elected institution that has been delegated its mandate by a primary lawmaker.[12] This occurs because modelling is part of assessment—an information, expert and communication-intensive process that can only be carried out by the administrative arm of government.[13] As we shall see, the fact that modelling is primarily occurring within the administrative realm has significant consequences for not only how models are understood, but also how lawyers and policy-makers interact with them.

Institutional mandate models include models which play a background policy-making role and those which directly inform particular decisions. Examples can be seen in air quality,[14] land contamination,[15] hazardous substances,[16] water quality,[17] flooding risk,[18] environmental assessment,[19] genetically modified organisms[20] and nature conservation.[21] Moreover, it also includes models deployed both formally and informally by private actors as

11 Fisher (n 1).
12 Ibid 19–22.
13 Ibid.
14 US Clean Air Act 42 USC §7409 (b)(1); Council Directive (EC) 96/62 of 27 September 1996 on ambient air quality assessment and management [1996] OJ L296/55 arts 4 and 6; Council Directive (EC) 2004/107 of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air [2005] OJ L23/3, Annex IV.
15 Department for the Environment Food and Rural Affairs, *Guidance on the Legal Definition of Contaminated Land* (DEFRA, London 2008).
16 Toxic Substances Control Act 15 USC §2605(a); Council Directive (EC) 98/8 of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market [1998] OJ L123/1 Annex VI, para 79; Commission Directive (EC) 95/36 of 14 July 1995 amending Council Directive 91/414/EEC concerning the placing of plant protection products on the market [1995] OJ L172/8, Annex II; Council Directive (EC) 2005/25 of 14 March 2005 amending Annex VI to Directive 91/414/EEC as regards plant protection products containing micro-organisms [2005] OJ L90/1, B.1.7.
17 Schedule 1, Water Act 2007 (Australia) and 33 USC §1313(d). See O Houck, *The Clean Water Act TMDL Program: Law, Policy and Implementation* (Environmental Law Institute, Washington, DC 1999).
18 Environment Agency, *Flooding in England: A National Assessment of Flood Risk* (Environment Agency, Bristol 2009).
19 42 USC §4332(2)(C) (1982) and 40 CFR §1502.22 (1987). See also R Smith, 'Lands Council v. Powell and the Ninth Circuit's Refusal to Blindly Refer to Unreliable Forest Service Science' (2007) 28 Public Land and Resources Law Review 65.
20 Commission Regulation (EC) 641/2004 of 6 April 2004 on detailed rules for the implementation of Regulation 1829/2003/EC of the European Parliament and of the Council as regards the application for the authorisation of new genetically modified food and feed, the notification of existing products and adventitious or technically unavoidable presence of genetically modified material which has benefited from a favourable risk evaluation [2002] OJ L265/1, Annex I, 2.E.5.
21 R Glicksman, 'Bridging Data Gaps Through Modelling and Evaluation of Surrogates: Use of Best Available Science to Protect Biological Diversity under the National Forest Management Act' (2008) 83 Indiana Law Journal 465.

part of the regulatory process so as to establish that a particular course of action that a private actor wishes to take is valid under a regulatory regime.[22] Examples here include the use of models in environmental impact assessment[23] and food and chemical licensing.[24] The fact that all these models are established with the primary purpose of fulfilling a legal mandate means that these models are deeply embedded within the legal and institutional cultures in which they are operating.

The final category of models is the emerging category of *regulatory strategy* models.[25] These models are tools for networking public and private actors into collaborative decision-making. Regulatory strategy models are not just a catalyst for action and/or an assessment tool but are also understood as a vehicle for collaborative deliberation between a diverse set of parties.[26] These models are thus explicitly crossing the science/policy divide. Moreover, regulatory strategy models are expected to be dynamic and those involved in decision-making are expected to be engaged with model development, interpretation and utilisation. In some cases these models will be part of a formal legal regime such as the EU Water Framework Directive,[27] but in other cases these models will be the focus of more informal forms of public/private negotiated governance.[28] The popularity of regulatory strategy models can particularly be seen in the context of integrated assessment where models are playing a significant role in reframing how historically sector-specific issues are understood.[29]

In each of the uses described above, models are not simply plugged into the regulatory machinery but are deeply intertwined into the structure and logic of environmental regulation. At its most obvious, the role of models is now being explicitly recognised in some legislative frameworks as part of the

22 Commission Regulation (EC) 641/2004 (n 20).

23 *R (on the application of Edwards) v Environment Agency* [2008] UKHL 22, [2008] 1 WLR 1587.

24 *Gulf South Insulation v CPSC* 701 F 2d 1137 (5th Cir 1983); Case T-13/99 *Pfizer Animal Health SA v Council* [2002] ECR II-3305.

25 M Van Asselt and N Rijkens-Klomp, 'A Look in the Mirror: Reflection on Participation in Integrated Assessment from a Methodological Perspective' (2002) 12 Global Environmental Change 167; O Renn and P-J Schweizer, 'Inclusive Risk Governance: Concepts and Application to Environmental Policy Making' (2009) 19 Environmental Policy and Governance 174.

26 C Prell and others, 'If You Have a Hammer Everything Looks Like a Nail: Traditional Versus Partcipatory Model Building' (2007) 32 Interdisciplinary Science Reviews 263.

27 Council Directive (EC) 2000/60 of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy [2000] OJ L327/1. B Page and M Kaika, 'The EU Water Framework Directive: Part 2. Policy Innovation and the Shifting Choreography of Governance' (2003) 13 European Environment 328.

28 Directorate Generals for Economic and Financial Affairs – Enterprise – Transport and Energy – Environment – Research and Taxation and Customs Union, *The Auto Oil II Programme: A Report from the Services of the European Commission* (2000) <http://ec.europa.eu/environment/archives/autooil/pdf/auto-oil.en.pdf> accessed 14 June 2010.

29 SEAMLESS and SEAMFRAME models integrating agricultural and environmental issues in the European Community. See <http://www.seamless-ip.org/> accessed 14 June 2010.

policy-making process[30] and there are also examples where regulatory institutions are producing substantial policy guidance concerning the use of models by private and public actors in order to provide some oversight over their use.[31] Regulatory institutions such as the US Environmental Protection Agency (EPA), moreover, have bodies that oversee modelling practice.[32] Most regulatory institutions in advanced democracies have modelling departments and dedicate considerable resources to modelling exercises.[33] These modellers are not isolated within the agency organisation, but instead are in regular communication with the agency's legal department, policy-making staffs and enforcement units. This process of institutionalisation means that modelling is part of the waft and weave of the regulatory fabric of a regime.[34] Modelling is not just fashion, easily shed with the new season, but rather is now a permanent feature in the institutional structure and logic of regulation.

1.2 Models and Disputes

It is not just that models are prevalent in environmental regulation, however. Disputes over them are also increasingly prevalent. Those disputes can be seen across all jurisdictions in both policy and legal contexts including political debate, policy discourse, media discussion and specific legal disputes.[35]

In the policy sphere many of these disputes have been in relation to policy-catalyst models. This is not surprising. As such models are establishing the premises for potential state action, it is obvious they will be controversial

30 Council Directive (EC) 2008/50 of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe [2008] OJ L152/1; Water Act 2007 (Australia) Schedule One; US S Rep No 106-410 (2001), 90, reporting that the 'Committee is concerned that EPA has not peer-reviewed the 3MRA risk assessment model,' <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=106.cong.reports&docid=f:sr410.106> accessed 14 June 2010.

31 US EPA, *Guidance on the Development, Evaluation and Application of Environmental Models* (EPA, Washington DC 2009) <http://www.epa.gov/crem/library/cred.guidance.0309.pdf> accessed 16 June 2010; New South Wales Department of Environment and Conservation, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (New South Wales Government Gazette, Sydney 2005).

32 Council for Regulatory Environmental Modelling (CREM). See <http://www.epa.gov/crem/index.html> accessed 14 June 2010.

33 The Environment Agency of England and Wales has an Air Quality Modelling and Assessment Unit (AQMAU) and see the European Topic Centre on Air and Climate Change which is contracted to the European Environment Agency.

34 US Government Accountability Office, *Human Health Risk Assessment: EPA Has Taken Steps to Strengthen Its Process, but Improvements Needed in Planning, Data Development, and Training* (Publication No GAO-06-595), 41. <http://www.gao.gov/new.items/d06595.pdf> accessed 16 June 2010.

35 D Michaels, *Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health* (OUP, New York 2008); case studies in P Harremoës and others (eds), The *Precautionary Principle in the Twentieth Century: Late Lessons From Early Warnings* (Earthscan Publications, London 2002).

with different actors arguing for and against such action.[36] Moreover, these disputes will also involve a range of public and private institutions as the models in question are derived from a range of sources.[37]

Disagreements over climate change models are again the most high profile examples of these types of disputes. Thus, for example, within popular science literature there has been a critique of some of the climate temperature models which have contributed to the understanding of climate change.[38] Likewise, the disclosure of emails derived from the hacking of the computer servers at the Climate Research Unit at the University of East Anglia gave rise to a debate over the validity of data related to particular modelling practices.[39]

Yet, policy disputes have also arisen in relation to institutional mandate models. There has been ongoing political discussion and commentary concerning the validity of models used in regulatory impact assessment and cost/benefit analysis.[40] Likewise, reports have focused on the validity of models used in different regulatory areas.[41] Particular controversies such as the banning of flights in European air space due to volcanic disruption in Iceland also led the models on which the ban was based to be discussed in the media.[42]

Disputes about models however, are not limited to the policy realm and there have been a growing number of legal challenges to regulatory action where models have been the focus. These disputes primarily concern judicial and merits review of administrative decision-making. This development has occurred in all jurisdictions, although most obviously in the United States due to both a tradition of intensive judicial review and a legal culture of adversarial legalism.[43] The legal arguments concerning models have been striking in

36 For examples see the two papers making up 'The Stern Review: A Dual Critique' (2006) 7 World Economics 165; the issues raised in *Downs v Secretary of State for Environment Food and Rural Affairs* [2009] Env LR 19; and A Macintosh, 'The Garnut Review's Targets and Trajectories: A Critique' (2009) 26 Environmental Planning And Law Journal 88. See the case studies in Michaels (n 35), and B Lomborg, *The Skeptical Environmentalist: Measuring the Real State of the World* (CUP, Cambridge 2001).

37 A W Montford, *The Hockey Stick Illusion: Climategate and the Corruption of Science* (Stacey International, London 2010).

38 R Pielke and T Wigley, 'Dangerous Assumptions' (2008) 452 Nature 531.

39 E Kintisch, 'Stolen E-mails Turn Up Heat on Climate Change Rhetoric' (2009) 326 Science 1329.

40 B Ackerman and L Heinzerling, *Priceless: On Knowing the Price of Everything and the Value of Nothing* (The New Press, New York 2004); S Shapiro, 'OMB and the Politicization of Risk Assessment' (2007) 37 Environmental Law 1083.

41 Royal Commission on Environmental Pollution, 'Crop Spraying and the Health of Residents and Bystanders' (The Stationery Office, London 2005) [6.10]; Royal Commission on Environmental Pollution, 'Novel Materials in the Environment: The Case of Nanotechnology' (Cm 7468, 2008) [3.115].

42 C Gammell, D Millward and B Waterfield, 'Volcanic Ash Cloud: Met Office Blamed For Unnecessary Six-day Closure' *Telegraph.co.uk* (London 19 April 2010) <http://www.telegraph.co.uk/news/7608722/Volcanic-ash-cloud-Met-Office-blamed-for-unnecessary-six-day-closure.html> accessed 5 May 2010; P Marks, 'Can we Fly Safely Through Volcanic Ash?' *New Scientist* (London 20 April 2010) <http://www.newscientist.com/article/dn18797-can-we-fly-safely-through-volcanic-ash.html> accessed 5 May 2010.

43 R Kagan, *Adversarial Legalism: The American Way of Law* (Harvard UP, Cambridge 2003).

their diversity. Thus, for example, legal arguments directly relevant to models have included:[44] that the procedures for considering a model were procedurally improper;[45] that a model was oversimplified;[46] that a model did not apply to a specific factual situation;[47] that the assumptions embedded in a model were incorrect;[48] that the data and statistics used in a model were flawed;[49] that the model was not subject to adequate peer review;[50] and that there was a better model or source of information which could be used.[51] There have also been some striking examples of where courts and tribunals have ruled that a specific model was incorrect.[52]

What is particularly interesting about these arguments is that nearly all of them require judges and lawyers to engage with the inner workings of models and the technical aspects of modelling practice. Moreover, while judges have tended to stress their lack of competence[53] and the importance of deference to expert discretion,[54] they have tended to consider arguments about models and modelling at length.

A good example of the type of legal issues raises by models can be seen in the recent English litigation concerning a challenge by a pesticides campaigner to the Department of Environment, Food and Rural Affair's (DEFRA's) decision not to implement no-spray buffer zones around agricultural land to protect rural residents.[55] The dispute was legally complex involving as it did a mixture of EU law, English principles of judicial review, and an intricate regulatory scheme. The claimant, Downs, argued (among other things) that there

44 Also see T McGarity and W Wagner, 'Legal Aspects of the Regulatory Use of Environmental Modeling' (2003) 33 Environmental Law Reporter 10751.

45 *R (on the application of Edwards)* (n 23); *McLouth Steel Products Corp v Thomas* 838 F2d 1317 (DC Cir 1988); and *Chemical Manufacturers Association v EPA* 28 F 3d 1259 (DC Cir 1994) (the *MDI* case).

46 *Small Refiner Lead Phase Down Taskforce v EPA* 705 F 2d 506 (DC Cir 1983); *Leather Industries Of America v EPA* 40 F 3d 392 (DC Cir 1994); and *Flue-Cured Tobacco Co-op v EPA* 4 F Supp 2d 435 (MD NC, 1998).

47 *Small Refiner* (n 46); *MDI* (n 45); *Edison Electric Institute v EPA* 2 F 3d 438 (DC Cir 1993).

48 *Gulf South Insulation* (n 24); *American Iron & Steel Institute v EPA* 115 F 3d 979 (DC Cir 1997); *Leather Industries of America* (n 46); *Downs* (n 36).

49 *American Iron & Steel Institute* (n 48); *Central Arizona Water Conservation District v EPA* 990 F 2d 1531 (9th Cir 1993); *Flue-Cured Tobacco Co-op* (n 46).

50 *Flue-Cured Tobacco Co-op* (n 46).

51 Case T-229/04 *Sweden v Commission* [2007] ECR I-2437; *Downs* (n 36); *Ulan Coal Mines Ltd v Minister for Planning* [2008] NSWLEC 185.

52 *Chlorine Chemistry Council v EPA* 206 F 3d 1286 (DC Cir 2000); *Xstrata Coal Queensland Pty Ltd* (n 9)

53 *Downs* (n 36) [38].

54 *Small Refiner* (n 46) 535; Case C-280/02 *Commission v France* [2004] ECR I-8573 and *Australian Pork Ltd v Director of Animal and Plant Quarantine* [2005] FCA 671.

55 *Downs* (n 36); *Secretary of State for Environment, Food and Rural Affairs v Downs* [2009] EWCA Civ 664, [2009] 3 CMLR 46. For a discussion of the case see L Warren, 'Healthy Crops or Healthy People? Balancing the Needs for Pest Control Against the Effect of Pesticides on Bystanders' (2009) 21 JEL 483.

was a failure to properly implement the relevant EU directive concerning pesticides.[56] The information on which the decision had been made involved a range of different studies and a risk assessment which included a model for bystander exposure. One of the claimant's arguments was that this model was in breach of the directive. The model had already been criticised by the Royal Commission on Environmental Pollution (RCEP) and that criticism has been subject to a response by DEFRA's Advisory Committee on Pesticides (ACP).[57]

In the Divisional Court, Collins J sketched in outline the different views of the parties on the adequacy of the bystander model but noted that 'I am not qualified to decide between those views nor is it an appropriate exercise for a judge to undertake on judicial review' unless there was evidence that the approach was 'tainted by irrationality in the *Wednesbury* sense'[58]—*Wednesbury* unreasonableness being the traditional and very high threshold test for substantive review in England and Wales.[59] Collins J also concluded that 'the alleged inadequacies of the model and the approach to authorisation and conditions of use have been scientifically justified'.[60] Later on, in relation to a different point he additionally noted:

> that a judge must be astute not to substitute his own view for that of the decision maker unless the decision maker has failed to have regard to a material factor, has had regard to an immaterial factor or has reached a truly perverse decision. The defendant in this case was bound to act on the advice given to him by experts. The advice conflicted and so he was entitled to choose between them.[61]

Yet he also found that the claimant had produced 'solid evidence . . . that residents have suffered harm to their health . . . or, at the very least, doubts have reasonably been raised as to the safety of pesticides under the regime which presently exists . . . It is clear that the precautionary principle must apply'.[62] The failure to consider this evidence as 'solid and that the conditions come within the scope of the Directive' was 'a failure to have regard to material considerations and a failure to apply the Directive properly'.[63] The requirement of 'solid evidence' was derived from a European Court of Justice (ECJ) judgment ruling on the same Directive where that Court found that

> It follows from that provision [Article 5(1) of Directive 91/441], interpreted in combination with the precautionary principle, that, in the

56 Council Directive 91/414/EC of 15 July 1991 concerning the placing of plant protection products on the market [1991] OJ L230/1. For her arguments see *Downs* (n 36) [6].
57 For a discussion of this see *Downs* (n 36) [4–5] and Warren (n 55) 492–4.
58 *Downs* (n 36) [38].
59 *Associated Provincial Picture Houses Ltd v Wednesbury Corporation* [1948] 1 KB 223.
60 *Downs* (n 36) [39]
61 Ibid [64].
62 Ibid [40].
63 Ibid [47].

> domain of human health, the existence of solid evidence which, while not resolving scientific uncertainty, may reasonably raise doubts as to the safety of a substance, justifies, in principle, the refusal to include that substance in Annex I to Directive 91/414.[64]

We will return to this judgment in a moment but it is also useful to note that Collins J also concluded that the failure to consider skin and eye irritancy was a failure to comply with the Directive.[65]

What this meant was that Collins J, through a different legal route, was effectively ruling on the adequacy of the model and in particular the types of information and exposure DEFRA had considered. This becomes particularly obvious when the ECJ's reference to 'solid evidence' is viewed in the context of its judgment where it made clear that the phrase must be seen in light of the principles of evaluation laid down in Annex VI of the Directive.[66] Those principles including references to modelling.[67] 'Solid evidence' was thus evidence which complied with principles of evaluation as set out in the Directive.

The case was appealed to the Court of Appeal. Downs argued that the bystander exposure model was not a 'suitable calculation model for residents', the language of 'suitable calculation model'[68] coming from the Directive.[69] Sullivan LJ concluded that:

> The Appellant was entitled to have regard to the ACP's views when considering what should be the Government's response to the RCEP's criticisms of the current model. Given that eminent scientists could not reach agreement as to whether there were significant shortcomings in the existing model, but were agreed that an improved model should be devised, even though they were not agreed as to whether it should be a probabilistic model, it is impossible to conclude that there is any error, much less a 'manifest error' in the Government's conclusions which are, in effect, that while the current approvals system is 'suitable' [for the purposes of the Directive] . . . . . because it is 'at the forefront of international standards and provides adequate protection for both spray operators and members of the public' (paragraph 44, Defra's Response), it should be reviewed against a 'more transparent model' which is not currently available, but which should be developed (paragraphs 45–6, Defra's Response).[70]

64 *Sweden* (n 51) [161].
65 *Downs* (n 36) [52].
66 *Sweden* (n 51) [167].
67 See B.1.5 of Annex VI of Directive 91/414/EEC (n 56).
68 *Secretary of State for Environment, Food and Rural Affairs* (n 55) [42].
69 Para 7.2.2. of Annex III of Council Directive 91/441/EEC (n 67).
70 *Secretary of State for Environment, Food and Rural Affairs* (n 55) [53].

In regard to the argument that DEFRA had ignored 'solid evidence' he concluded that:

> The Report, the Commentary and the RCEP's Response all make it clear that there is no consensus in the scientific community that there is 'solid evidence' as found by Collins J. In Defra's response the Appellant did not accept that there was such evidence (paragraph 81 above). Collins J. was not entitled to substitute his own view for that of the Appellant, and in the absence of such a scientific consensus, had Collins J. applied the 'manifest error' test, he would have been bound to conclude that there was no manifest error in the Appellant's approach to the issue of causality.[71]

Our analysis of the above does not do justice to what was a very complex piece of litigation but these cases are paradigm examples of how models become the focus in legal disputes. Moreover, it highlights three things. First, despite statements that scientific issues were not within the competence of judges, the judgments by the Divisional Court and the Court of Appeal were both lengthy and detailed. This is even when, as with the Court of Appeal, they ultimately upheld the decision. Second, the legal arguments concerning the bystander exposure model were not just 'Is this right or wrong?' but involved a series of complex and overlapping legal arguments derived from different sources—was the model a 'suitable calculation model', was there 'solid evidence', was there a 'manifest error of assessment?' These are all arguments with a very real legal dimension. Third, the courts in these cases were not only engaging with the details of the bystander exposure model but also the administrative process in which it was embedded.

1.3 The Lack of Sustained Engagement with Models by Lawyers and Policy-Makers

At this stage in our analysis two points need to be made. First, there is nothing novel in us identifying the important role models are playing in environmental regulation. In recent years many academic commentators,[72]

71 Ibid [61].

72 Holmes and others (n 10); S Yearley, 'Sociology and Climate Change After Kyoto: What Roles for Social Science in Understanding Climate Change?' (2009) 57 Current Sociology 389; A Petersen, 'Models as Technological Artefacts' (2000) 30 Social Studies of Science 793; S Rayner and E Malone (eds) *Human Choice and Climate Change, Volume One: The Societal Framework* (Pacific Northwest National Laboratory, Battelle Press, Columbus 1998); and M Lahsen, 'Seductive Simulations? Uncertainty Distribution Around Climate Models' (2005) 35 Social Studies of Science 895.

decision-makers[73] and even novelists[74] have pointed to the significance of models. The most high profile has been the highly respected US NRC which published *Models in Environmental Regulatory Decision-Making* in late 2007.[75] Moreover, most of these publications have highlighted the complexity of models.

Second, despite all of the above and the types of disputes seen in *Downs*, most policy-makers and lawyers have shown little sustained interest in the substance of models or the nature of modelling practice. These publications have been met mainly with silence and there has been no ongoing policy or legal dialogue concerning the nature of models, beyond the work of a few specialists. More significantly, on being faced with a model, many lawyers and policy-makers are only interested in asking the 'plain man's question', namely does the model amount to a 'real prediction?',[76] but they are not interested in probing further.

As seen in the previous section, specific cases or disputes may force a policy-maker or lawyer to engage with the inner workings of a particular model but this engagement is invariably in the time-pressured context of that case or dispute. In this context there is often a heavy reliance on different forms of deference whether it be to particular experts, administrative institutions, or decision-making processes.[77] The discussion of any particular model is in isolation and there is no precedent concerning models and just as a case is distinguishable on its facts, it is understood to be distinguishable in regards to the model.

We explicitly highlight this lack of sustained engagement with models by lawyers and policy-makers because it has been ignored in much of the literature. Indeed, many articles on models proceed on the assumption that the relevance of the substance of models to lawyers and policy-makers is self-evident. Yet we would argue that is not the case. Moreover, we would argue that this lack of substantive engagement is largely due to two different reasons.

First, models are perceived by lawyers and policy-makers to be 'scientific' and thus not within their expertise. Thus, while the outcomes of models are understood as relevant to law and policy, the inner workings of models—fat tails, uncertainty analysis, model coding, stochasticity, parameter variation, methods of corroboration and so on—are all understood to belong to the province of science. This view is of course not unfounded—models present a 'thicket of

73 P Pascual, 'Wresting Environmental Decisions From an Uncertain World' (2005) 35 Environmental Law Reporter 10539.

74 M Crichton, *State of Fear* (HarperCollins, New York 2004).

75 NRC (n 3).

76 J Ravetz, 'Models as Metaphors', in B Kasemir and others (eds) *Public Participation in Sustainability Science: A Handbook* (CUP, Cambridge 2003) 75.

77 *Secretary of State for Environment, Food and Rural Affairs* (n 55) [91] (assessing the view in the scientific community); WTO Panel Report, *Japan—Measures Affecting Agricultural Products (Varietals)*, AB-1998-8, 22 February 1999, [8.32] (deference to expert panel).

formulae and computer codes',[78] which require specialist knowledge to navigate—a thicket which is a barrier to understanding.

Second, for lawyers in particular, whose focus is upon law and its application, models are seemingly too much part of what occurs in the back office of administrative practice—they are not where the legal focus has traditionally been. To engage with an environmental model is thus also to engage with large expanses of the administrative landscape and its organisation and operation. Thus, cases in which models are subject to legal dispute often contain lengthy examinations of the role of different decision-making bodies and their relationship to each other. For example, in *Downs* both the Divisional Court and the Court of Appeal spent much time explaining the relationship and interactions between RCEP and ACP.[79]

The lack of engagement with models can thus be seen as due to a perception that models are neither within the *expertise or traditional domain* of what lawyers and policy-makers do. Yet what the disputes highlight in the last section is that, despite this, models are clearly *relevant* in some way to what lawyers and policy-makers do. What can be seen in cases like *Downs* is that the issues to do with modelling cannot be untangled from legal questions. Models are not just facts, but raise issues for the application of the law. This point was well made by the Australian Federal Court in relation to another modelling case where it noted:

> There is an added level of complexity in cases such as the present where the exercise of a statutory discretion is preceded by fact finding and it is sought to allege that irrationality and capriciousness have tainted both parts of the process and where the exercise of power is informed, in part, by scientific predictions.[80]

Thus, in *Downs* the 'bystander exposure model' sparked arguments about whether DEFRA had understood its legal obligations properly. Likewise, in other cases, the use and interpretation of models has raised issues to do with procedural fairness and legislative interpretation.[81] These cases thus highlight that models are relevant to what lawyers and policy-makers do—the question now raised is why that is the case?

78 Ravetz (n 76) 70.

79 See eg the discussions of the administrative frameworks in *Downs* and as re-described in *Secretary of State for Environment, Food and Rural Affairs* (n 55). Other examples include Case T-13/99 *Pfizer* (n 24) and *Australian Pork Ltd* (n 54).

80 *Lawyers for Forests Inc v Minister for the Environment Heritage and the Arts* [2009] FCA 330, [86].

81 Case T-13/99 *Pfizer* (n 24); *R (on the application of Eisai Ltd) v National Institute for Health and Clinical Excellence* [2008] EWCA Civ 438, (2008) 11 CCL Rep 385.

2. Why Models are Relevant to Lawyers and Policy-Makers

To answer that question our approach is conceptual and returns back to two more basic questions. What are the key features of models in environmental regulation and what role are they playing in that context? In answering this question it needs to be acknowledged that models have made a long, varied and important contribution to the sciences and social sciences,[82] but our focus is only on their use within the regulatory context.

2.1 Five Key Things to Know About Models

If we return to our bland definition of a model that we quoted in Section 1 it can be seen that models are 'a simplification of reality that are constructed to gain insights into select attributes of a particular . . . .system'.[83] Using this definition as a springboard there are five key things to note about models in environmental regulation.

First, models are simplifications of reality.[84] Or to put the matter another way—a model is not reality. A model of a river basin will only capture some elements of that ecosystem just as a model of the solar system only captures some elements of the planets and their relationship to the sun. In relation to environmental regulations, models are particularly useful because the systems they represent are so complex and open ended that they can be difficult to conceptualise.[85] As Oreskes notes:

> Complex earth systems – such as the climate response to increased carbon dioxide, the transport of contaminants through groundwater, or the workings of a forest ecosystem – are difficult to address by traditional scientific methods. An ecosystem cannot be brought into the laboratory; the Earth's climate cannot be the site of controlled experiments. If you had proposed adding carbon dioxide to the Earth's atmosphere to test its effects, the experiment would have been rejected on ethical grounds. Numerical simulation models provide an ethical and pragmatic means to grapple with complex natural systems. [86]

82 M Hesse, *Models and Analogies in Science* (University of Notre Dame Press, Notre Dame 1966) and A Creager and others (eds) *Science Without Laws: Model Systems, Cases, Exemplary Narratives* (Duke University Press, Durham 2007).
83 NRC (n 3) 31.
84 Ibid 31.
85 N Oreskes, 'Why Believe a Computer? Models, Measures, and Meaning in the Natural World' in J Schneiderman (ed), *The Earth Around Us: Maintaining a Livable Planet* (WH Freeman and Co, San Francisco 2000) 73.
86 Ibid 73.

Moreover, models are frames that enable 'better questioning, exploration, handling and manipulation of the topic'.[87] As frames, models will draw (among other things) on both scientific theories about how a system works and available data about that system.[88] Models may draw on a single scientific discipline or many,[89] and they may be adapted as information and disciplinary understandings change.[90]

One of the most common types of model used in environmental regulation are computational models developed by selecting different elements of a system and formalising relationships among these elements through mathematical equations that are then codified in a computer program.[91] That computer program is not reality however. Nor is it a 'truth telling machine'[92] or a 'fact'.[93]

Second, for a model to be able to provide insight it must be a *rigorous* representation of reality. It must have a level of rigour that is defensible as fit for the purpose in hand. A model of ocean currents which is based on no data and a presumption that the world is flat is clearly inferior to one incorporating ocean current data and grounded in the theory that the world is round. A good model will be a coherent representation of a system that is based on well-established scientific theories and relevant, quality data. To say this is not to say that models are facts or that a model's truth can be validated. Rather it is saying that despite this, distinctions can be made in the quality of models. Moreover, the quality of a model will determine the quality of the insight which can be gained from it. Of course that raises the difficult question of how quality is judged and who is to judge it—this is an issue raised in many of the disputes above.

Third, as a simplification of reality a model is constructed for a purpose or set of purposes. That purpose is defined by the NRC as 'gaining insight'[94] but this should be understood in context. In the environmental regulatory context the main role of models is not so much to gain disinterested insight into a particular system but rather models are developed to assist decision-makers in discharging their regulatory responsibilities. Those responsibilities can vary dramatically but generally speaking models are concerned with assessing the existing state of the environment, human health and the economy, and predicting impacts on these different things. This will be considered in detail in the next section.

87 M Meyer, 'Increasing the Frame: Interdisciplinarity, Transdisciplinarity, and Representativity' (2007) 32 Interdisciplinary Science Reviews 203, 209.
88 M Morrison and M Morgan, 'Models as Mediating Instruments', in M Morgan and M Morrison (eds), *Models as Mediators* (CUP, Cambridge 1999) .
89 Lahsen (n 72) 898.
90 I Grosse and others, 'Ontologies for Supporting Engineering Analysis Models' (2005) 19 Artificial Intelligence for Engineering Design, Analysis and Manufacturing 1.
91 NRC (n 3) 32.
92 Holmes and others (n 10) 161; NRC (n 3) 21.
93 NRC (n 3) 3.
94 NRC (n 3) 31.

Fourth, the purpose or purposes for which a model is developed will directly influence how reality is simplified. Thus, for example, if a model is being developed to assess water quality in a river then a model may represent water flow, oxygen concentration and contaminants but is unlikely to represent how many rocks are in the river or how many bridges cross it. In other words, the regulatory purposes of a model will influence what it represents. Moreover, the purposes of a model will directly influence how simplified the representation of a model is. Thus, for example, a model may be oversimplified to increase transparency of a system or the use of a system by non-scientists.[95] Models, then are not just products of theory and data but are also shaped by the priorities of the decision-makers who are deploying them.

Fifth, a logical consequence of all of the above is that modelling is an interdisciplinary activity. This is in two different ways—internally and externally. *Internally,* the process of modelling itself requires the integration of many different forms of information and assumptions from a variety of different disciplines.[96] Thus, while modelling is a distinct activity, it is only semi-autonomous in nature as it is drawing on a range of different disciplines.[97] Modelling also has an *external* interdisciplinary aspect because it is being carried out for a set of regulatory and policy-making purposes. Modelling is not just a scientific activity which is of relevance to policy-makers, but a scientific activity developed *for* policy-makers with the purposes of policy-making in mind.[98] Indeed, a model can be understood as a 'boundary object' in that it is a technical 'object' that inhabits 'several intersecting social worlds . . . and satisf[ies] the informational requirements of each of them'.[99]

2.2 The Role of Models in Environmental Regulation

The discussion so far has established that modelling is a semi-autonomous and interdisciplinary activity concerned with developing representations of reality for a purpose or purposes where that purpose or those purposes will influence how reality is represented. It is thus important to focus on the role of models in environmental regulation. What such a focus makes very obvious is that models are not just playing a back office and/or scientific role but rather are making a major contribution to regulating administrative behaviour and thus to establishing the legitimacy of administrative decision-making.

95 Holmes and others (n 10) 159.

96 P Pascual, 'Avoiding Tragedies of the Intellectual Commons through Integrated Impact Assessments' (2007) 21 Water Resources and Management 2005.

97 Morrison and Morgan (n 88).

98 In this regard it can be thought of as part of 'regulatory science'. See S Jasanoff, *The Fifth Branch: Science Advisers as Policy Makers* (Harvard UP, Cambridge 1990) 81.

99 S Leigh Star and J Greisemer, 'Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39' (1989) 19 Social Studies of Science 387, 393. Also see Pascual (n 96).

As seen above, it can be generally said that models are an activity of assessment. Assessment is the means by which regulators determine the existing states of, and predict future impacts of particular activities on, the environment, human health, the economy and society. Most of the time, they will be doing this in pursuance of their regulatory responsibilities. This is why institutional mandate models make up the vast bulk of models in environmental regulation. There are many examples of different assessment tools developed by regulators for specific purposes such as risk assessment, regulatory impact assessment and environmental impact assessment.[100] Models can be integrated into these tools but also can operate independently from them.

As part of assessment, models as workable representations of complex systems have three particular purposes. First, models are 'succinctly encoded' archives of existing knowledge about a particular system.[101] The knowledge that is being archived is often from disparate disciplinary sources including monitoring data, epidemiology studies, toxicology studies and expert opinion. Such information may also be of erratic quality and can range from raw observational data to theoretical assumptions. The way in which models can collate knowledge makes their utility to the regulatory process obvious—they increase the potential that the weight of available information about a system will inform regulatory decision-making.

The second purpose of models in the assessment context is to organise and integrate this information by placing it into a formalised construct that relates different pieces of information to each other. That construct is the simplified representation of reality and as we saw above a model is a powerful frame which aids focus.[102] As such models will dictate what is relevant and irrelevant to consider. Models are thus not just tools for collating information but also interpreting and making sense of that information. The rigor and quality with which a model does this can vary dramatically. Moreover, different models will frame issues differently and thus result in divergent understandings and interpretations of issues.[103]

The third purpose of a model is to serve as a tool of prediction. One aspect of environmental regulation is that it is an *ex ante* activity which seeks to regulate future human activity.[104] To do that, assessment tools are required to determine what the potential impacts of that human activity are. Prediction is an inherently uncertain process but models, by collating available information, may potentially reduce those uncertainties. At the same time however, because

100 NRC, *Risk Assessment in the Federal Government: Managing the Process* (National Academy Press, Washington, DC 1983); C Sunstein, *The Cost Benefit State: The Future of Regulatory Protection* (American Bar Association, Washington, DC 2002); J Holder, *Environmental Assessment: The Regulation of Decision-Making* (OUP, Oxford 2005).

101 NRC (n 3) 25.

102 Meyer (n 87).

103 E Tufte, *The Visual Display of Quatntitative Information* (Graphics Press, Cheshire 2001).

104 C Sunstein, *The Partial Constitution* (Harvard UP, Cambridge 1993).

models are shaped by their purposes and uncertainty still exists, modelling is neither a perfect nor a solely factual tool of prediction.

A single model may be developed for all three purposes or only one. Likewise, a model may be developed for one purpose and used for another. In all cases however, models are playing a role in ascertaining the relationship between the activity being regulated and the regulatory aim to be achieved. The significance of this is that models are ascertaining the premises and rationale of regulatory action. They are ascertaining the premises of regulation because models, through the collation and interpretation of knowledge, are a tool for identifying problems that need regulatory responses. They are establishing the rationale because through interpretation and prediction a model can direct what form that regulatory response should take.

In other words models, when relied on in regulatory decision-making, are regulating the power of a regulator in that a model is intended to 'govern behaviour',[105] particularly in relation to defining what is reasonable action on the part of a decision-maker. Models are laying down a blueprint for identifying which decisions are 'worthy' to be recognised as authoritative—or in other words as legitimate.[106] Models are thus playing a normative role in that they are part of a decision-making framework telling decision-makers what they ought to do.

Our analysis above has been very basic, but this stark analysis helps in aiding an understanding of why models, and in particular the inner workings of models, are of relevance to lawyers and policy-makers. Models are clearly setting the limits of legitimate action and therefore directly relevant to legal and policy questions concerning what is it reasonable for a decision-maker to do. If the model is understood to be legitimate, and it is followed by a decision-maker, then the decision-maker's decision is understood to be legitimate. However, if the decision-maker, does not follow a model they are expected to follow then the legitimacy of the final decision is open to question. Models thus limit and direct regulatory power.

Yet the relevance of models does not stop there. If models are regulating power then it becomes very important that the models themselves are legitimate. As such, the substance and detail of models become relevant to lawyers and policy-makers. If a model is understood as a rigorous representation of reality then it can be understood as a legitimate basis for action. If a model is understood to be of poor quality then it is not. That is why in cases such as *Downs* the Divisional Court and Court of Appeal were faced with many arguments about the legitimacy of the bystander exposure model and the other types of assessment undertaken by DEFRA. If these exercises in modelling and assessment were found to be problematic then so too would be the exercise

105 H Collins, *Regulating Contracts* (OUP, Oxford 1999) 7.

106 On worthiness and legitimacy see J Habermas, *Communication and the Evolution of Society* (The Polity Press, Cambridge 1984) 178.

of discretion based on that assessment. To put it bluntly—the quality of models directly affects the quality of law and policy.

3. Models and Complexities

At this stage, the reaction of readers to our analysis of why models are relevant to policy and law may be to conclude that the appropriate response is to rush out to read a modelling textbook. But that is not our argument—our argument is that, on appreciating that models are relevant to what lawyers and policy-makers, there is also a need to appreciate the intellectual challenges in dealing with models. These intellectual challenges arise from the nature and role of models in environmental regulation

Those intellectual challenges are many but here we begin to identify some of them by discussing four different sets of complexities created by models in environmental regulation. First, there is a set of technical complexities due to the fact that models are representations of reality where data is imperfect, systems are not always well understood, and theories are capable of revision. Second, there is institutional complexity because there is an ongoing interrelationship between how models are developed and the institutional context in which they are operating. The third complexity is interdisciplinary complexity due to models straddling the science/policy divide. The fourth and final form of complexity is that there is a need to evaluate the quality of models. This however is not a straightforward task.

3.1 Technical Complexity

The first type of complexity is technical complexity. By this we mean that modelling is complex due to the fact that it operates in conditions of uncertainty and the structure and nature of models is open to variation. The technical complexity of models has been well discussed by commentators arguing the need for them to be treated with care and there is a voluminous literature on the topic.[107] That literature, while very valuable, can also be overwhelming to the novice particularly because in identifying many different forms of uncertainty it quickly becomes enmeshed in the technical detail. Moreover, at times the literature can veer into Rumsfeldian farce with its discussion of different

107 K Beven, *Environmental Modelling: An Uncertain Future?* (Routledge, London 2009); N Oreskes, 'Evaluation (Not Validation) of Quantitative Models' (1998) 106 Environmental Health Perspectives 1453; Jasanoff and Wynne (n 5); D Frame and others 'Probabilistic Climate Forecasts and Inductive Problems' (2007) 365 Philosophical Transactions of the Royal Society A 1971.

types of uncertainty.[108] Indeed, while those who write about uncertainty hope to 'de-mystify' objectivity, their discussion of the concept can often do the opposite.[109] For these reasons, in this section, we take a simpler route by highlighting the different sources of uncertainty and the different reasons why models are variable.

The most important point to appreciate is that scientific uncertainty is inherent in all parts of the process of environmental modelling. As a first step, the modeller must decide which elements of a system she should focus on; uncertainty already pervades this choice, as the modeller exercises some expert judgment in determining whether she has properly identified the components driving the system she wishes to model. Secondly, the modeller collects data about the system, a process replete with uncertainties about whether she has chosen and properly applied the correct method to gather representative data that characterise how the system operates. Even when the modeller has properly executed these first two steps, it is often the case that multiple mathematical equations can describe the same data set. It is therefore the case that uncertainty inevitably permeates the *development* of environmental models.

When a model is *used* for a specific regulatory application—such as to establish discharge limits for nitrogen in an estuary—another source of uncertainty arises. It is usually the case that the features of the system being modelled vary over time and space. Because a model may have been developed based on an initial set of conditions, the model developer and user must determine whether a model is sufficiently robust to use even when these conditions have changed. This determination, too, is subject to uncertainty.

In relation to each source of uncertainty, the nature of uncertainty will vary depending on the available data and the rigour with which the features of a particular system are understood. The natural environment is a holistic system made up of numerous complex and little understood interrelationships. Likewise social phenomena are not easily subject to predictive analysis and as Rayner and Malone note we 'have inaccurate and conflicting theories about how and why people make choices, for themselves and in societies'.[110] Thus, for each source of uncertainty there is a range of methodological, epistemological and even ontological issues which manifest themselves as a tangled web of complex uncertainties. Uncertainty is not always reducible through additional data. Furthermore, irreducible ignorance about a complex system

108 D Logan, 'Known Knowns, Known Unknowns, Unknown Unknowns and the Propagation of Scientific Enquiry' (2009) 60 Journal of Experimental Botany 712 and S Dovers and J Handmer, 'Ignorance, Sustainability and the Precautionary Principle' in R Harding and E Fisher (eds), *Perspectives on the Precautionary Principle* (Federation Press, Sydney 1999).

109 G Bammer and M Smithson (eds), *Uncertainty and Risk: Multidisciplinary Perspectives* (Earthscan, London 2008) xiv.

110 S Rayner and E Malone (eds), *Human Choice and Climate Change – Volume Four* (Pacific Northwest National Laboratory, Battelle Press, Columbus, OH 1998) 120.

will always be an inherent feature of modelling. It is for these reasons that the literature on uncertainty in modelling can appear so impenetrable.

The fact that modelling is shrouded in uncertainty has three important implications for policy-makers and lawyers. First, models cannot be expected to deliver certainty. They cannot generate facts and they cannot generate definitive answers. Any argument based on such an assumption is wrong. Likewise, to criticise models for not generating certainty is also wrong. Second, it is important for policy-makers and lawyers to have some understanding about uncertainty in modelling. Such an understanding significantly increases the effective and proper utilisation of models as policy-makers and lawyers would have a better appreciation of what it is valid to expect, and not to expect, from models. Third, uncertainties (and the fact that models are developed for a purpose) mean that embodied in models are also professional judgements, values and assumptions about the world. These are often described as forms of undesirable subjectivity but the reality is that these features of models are necessary to make models operate. The issue is thus not removing these unavoidable features of models, but being able to evaluate the quality of these assumptions. To do that, some transparency is required but the technical complexity of models makes such transparency difficult to achieve.

Uncertainty also creates another form of technical complexity. In light of uncertainty, a single physical system can be validly modelled in a number of different ways. As Beven notes:

> .... [A]chieving '*the*' model of an environmental system may be fraught with difficulty. Instead, there may be different model structures, and parameter sets within model structures, that are consistent in some sense with the uncertainties in the available data, and many different ways of estimating uncertainty in the predictions.[111]

In other words, models are not innately objective scientific constructs that—if done correctly—yield a single, verifiable depiction of reality. Rather, even when developed according to the best principles of science, models may yield multiple versions of reality, each of which may be perfectly valid on its own terms in a way that is logically consistent with the assumptions and framework used to develop the model. This is a technical complexity in itself because rigorous modelling is not an inflexible formula yielding strict results but something far more creative (albeit still highly disciplined).

Modelling is about fashioning and moulding data, assumptions, uncertainties and theories. In this sense it is akin to sculpting[112]—it is inherently a transformative enterprise in that as a semi-autonomous activity it is creating

111 Beven (n 107) 251.

112 Michaels (n 35) 68; J Smith and P Smith, *Environmental Modelling: An Introduction* (OUP, Oxford 2007) 2.

a representation. Recognising that fact is not to recognise that models are simply fictions, but rather that modelling is working with highly malleable matter. The consequences of this malleability is not just that a model can take a variety of forms but also that there are real challenges in determining what is a valid model. In light of the malleability, the determination of what is a valid model cannot simply be on the basis of it conforming to a single construct or a single process—other criteria need to be developed.

Again, all of this has major implications for policy-makers and lawyers. First, there cannot be an assumption that modelling is about developing a single perfect representation of a system. Any arguments based on this belief are wrong. Second, it is increasingly clear that the characterisation of models as being purely 'scientific' and 'objective' is naive. Indeed, a study of the technical complexity of models makes increasingly obvious the problematic nature of understanding regulatory decision-making in terms of the science/policy division. Third, and following on from above, a more sophisticated understanding is needed of how to evaluate models. This is discussed in Section 3.4.

3.2 Institutional Complexity of Models

Models are not only technically complex however. They are also institutionally complex.[113] This is due to the fact that models interact with the institutional context in which they operate. Moreover, the interactions between a model and its institutional context are multi-dimensional and subtle and can seem overwhelming to the uninitiated.[114] Models are developed for regulatory purposes and those regulatory purposes will influence how models are developed. Models regulate power and thus their use relates to the legitimacy of regulatory decision-making. Models are increasingly institutionalised and the subject of policy and legal disputes. Models are thus part of the administrative and legal landscape. As with technical complexity, we do not aim to survey the whole of institutional complexity but rather seek to highlight one aspect of this complexity—the way in which models are conceptualised in policy and legal discussions is heavily dependent on what is understood to be legitimate public administration.

As we saw above, models are playing a normative role in establishing the authority of decisions. They are doing so against a background in which the authority of regulatory decision-makers is more generally contested.[115]

113 Yearley (n 72).

114 This can particularly be seen in the related area of financial models. See G Tett, *Fool's Gold: How Unrestrained Greed Corrupted a Dream, Shattered Global Markets and Unleashed a Catastrophe* (Little Brown, London 2009).

115 B Cook, *Bureaucracy and Self Government: Reconsidering the Role of Public Administration in American Government* (Johns Hopkins UP, Baltimore, MD 1996); Fisher (n 1).

The reason for this is not just that environmental issues themselves are controversial[116] but also, more significantly, because decision-makers are administrative.[117] Not only is it the fact that unelected administrative power has a paradoxical position in liberal democracy, but the wide and opaque discretion required in environmental regulation only exacerbates that paradox and makes administrative power even more difficult to justify.[118] Indeed, the history of environmental regulation in most jurisdictions has been a history of an ongoing legal and policy debate about what is, and should be, the role of public administration.[119] A feature of this history has been how assumptions about what a regulator *should do* influences what is understood a regulator *is* doing.[120] Legal and policy disputes are invariably about which assumptions about good public administration should dominate.[121]

The issue in regard to models is thus what assumptions are made about them by policy-makers and lawyers about what it is they contribute to the administrative process to ensure that process is legitimate. In policy and legal debates we can see two broad characterisations of modelling—as an analytical-deliberative process *or* as a method for generating truth. It is important to remember that these characterisations are based on assumptions about what it is an environmental regulator is *expected to do*. They reflect the institutional complexity of models because they highlight the fact that models are understood and conceptualised in their institutional context—a context which is contested.

The first characterisation of modelling is that seen in this article—where modelling is understood as an 'analytical-deliberative process'. That is models are understood as a process for helping frame issues so as to allow sharper and more rigorous focus on them. This aids analysis, deliberation and problem solving. Thus, as the NRC notes:

> Models provide a framework that defines the relationships that are valuable to study and specify how measured quantities are to be interpreted in the real world.[122]

By doing this a model allows for the development of more rigorous approaches to examining a problem and allows for actors to discuss issues in a more sophisticated way. At the same time, however, modelling is understood to be a

116 J Dryzek, *The Politics of the Earth: Environmental Discourses* (2nd edn OUP, Oxford 2005).
117 Fisher (n 1) 19–22.
118 Ibid.
119 S Shapiro and R Glicksman, *Risk Regulation At Risk: Restoring A Pragmatic Approach* (Stanford UP, Stanford 2003); C Sunstein, *Risk and Reason: Safety, Law and the Environment* (CUP, Cambridge 2002); T McGarity, 'A Cost Benefit State' (1998) 50 Administrative Law Review 7.
120 J Mashaw, *Greed, Chaos and Governance: Using Public Choice to Improve Public Law* (Yale UP, New Haven 1997) 1–29.
121 Fisher (n 1) 53–241.
122 NRC, *Understanding Risk: Informing Decisions in a Democratic Society* (National Academy Press, Washington DC 1996) 100.

limited method due to uncertainty, the fact that a model is always a representation, and that the systems being modelled are holistic, open ended and dynamic. Models don't generate final answers but they do generate useful 'insights' that aid both deliberation and analysis.

This characterisation of modelling does not exist in isolation however. If models and environmental problems are understood as complex then it is also understood that the role of public administration must be about solving complex problems shrouded in uncertainties. Indeed, understandings of modelling as an analytic-deliberative method coexist with a more general understanding of public administration as a deliberative-constitutive (DC) institution. By this we mean that public administration is understood to be constituted as a substantive institution which is engaging in on-going problem solving through the exercise of flexible discretion based on deliberation and analysis.[123]

While the characterisation of modelling as an 'analytic-deliberative' process is common among those who are either engaged in modelling or work closely with models,[124] it is not the characterisation that has predominated among lawyers and policy-makers. This is not because these groups have formed any strong views about the nature of models. Rather, their views of models have been shaped by their views about the desired role of public administration which they understand as needing to be as restrained and controlled as much as possible.[125] For this group, the DC paradigm with its emphasis on flexible deliberation and analysis is problematic because it grants too much discretion to the decision-maker. Rather, those concerned with control of public administration have tended to promote the rational-instrumental (RI) paradigm of public administration. On this basis, public administration is understood as akin to a robot or a 'transmission belt'[126] that applies the 'facts' to specific legislative commands. Facts include information rigorously policed by scientific and social scientific methodology and preferences voiced through a fair, pluralist participatory process.[127] Reasonable RI administrative action is to carry out this process of application in the most efficient and effective manner possible and RI administration is understood as legitimate because the problems that RI administration is dealing with are understood to be inherently manageable.

If the role of public administration is understood in RI terms then it becomes inevitable that models are understood as 'truth generators' producing the truth which then can be applied to a legislative mandate. In other words,

123 Fisher (n 1) 30–2.

124 M B Beck (ed), *Environmental Foresight and Models: A Manifesto* (Elsevier, Amsterdam 2002); E Fisher, 'Drowning by Numbers: Standard Setting in Risk Regulation and the Pursuit of Accountable Public Administration' (2000) 20 OJLS 109.

125 Ibid.

126 R Stewart, 'The Reformation of American Administrative Law' (1975) 88 Harvard Law Review 1661.

127 Fisher (n 1) 29.

Table 1. Two paradigms of models and their relationship to ideals of good public administration and understandings of environmental problems

	Analytic-deliberative method	**Fact generating**
Conceptualisation of modelling	Models as constructs to assist in problem solving, deliberation and analysis	Models as scientific constructs that produce truth.
Nature of environmental problems and scientific uncertainty	Complex and dynamic. Uncertainty as inevitable and irreducible	Manageable and easily assessed. Uncertainty as undesirable and needing to be avoided.
Public administration[a]	Deliberative-constitutive: constituted to engage in ongoing, flexible problem solving grounded in analysis and deliberation	Rational-instrumental: limited agent of the legislature that applies the facts (including public preferences) to legislative mandates.

[a]Fisher (n 1) ch 1.

models are not understood as representations produced for particular purposes but rather as scientific reality. On this basis, modelling is presumed to be able to capture reality accurately and uncertainty is an avoidable nuisance. For models to be able to do this then reality needs to be presumed to be easily captured by the process of modelling. The problems created by open ended, holistic ecosystems thus need to be downplayed. As is clear from our analysis so far, this characterisation of models is simply wrong.[128] Thus, while the accountability impulse behind the RI paradigm is understandable, the conceptualisation of models that it promotes is deeply misleading.

There are three implications of all of this. First, models are not understood in isolation. The way in which models are conceptualised is highly dependent on broader understandings of legitimate public administration and environmental problems. Those broader relationships are summarised in Table 1.

Second, an implication of these relationships is that lawyers and policy-makers will always be characterising models even when they are not explicitly engaging with them. Thus in the disputes seen above, lawyers and policy-makers are making assumptions about models. For example, Collins J understood the existence of what he understood as 'solid evidence' as a need to rethink the model to make it a more accurate factual construct.[129] The fact it was not, meant, that for him, DEFRA was not in compliance with the Directive. In contrast, the Court of Appeal understood the model as a heuristic tool that captured general scientific consensus but which would change over time.[130] The point about these assumptions is that they are not based on explicit engagement with models but rather are dependent on broader

128 Wagner and others (n 2).
129 *Downs* (n 36) [46]–[47].
130 *Secretary of State for Environment, Food and Rural Affairs* (n 55) [76]–[91].

understanding of public administration. Thus, Collins J analysis was resting on a RI understanding of public administration and the Court of Appeal's analysis was resting on a DC understanding.

Third, what this means is that in thinking about models, lawyers and policy-makers must also reflect on their understandings of good public administration and environmental problems. Indeed, the analysis above forces lawyers and policy-makers to reflect upon the logic behind a RI model of public administration in particular. While such a model is appealing because of the control of public administration it seems to offer up, it is deeply problematic in how it characterises the role a model can play.[131]

In highlighting these implications it should be remembered that the relationship between models and paradigms of good public administration is only one aspect of institutional complexity. There are also many others. For lawyers and policy-makers, the major implication of this form of complexity is that models cannot be viewed in scientific and technical isolation but rather must be analysed as part of the institutional context in which they operate. That may require lawyers and policy-makers to broaden their intellectual field of vision.

3.3 Interdisciplinary Complexity

The third form of complexity that needs to be engaged with in relation to policy-makers and lawyers engaging with models is interdisciplinary complexity. Interdisciplinary complexity has three main aspects.

The first type of interdisciplinary complexity is that models themselves are often interdisciplinary constructs, particularly those models developed by integrated assessment which incorporate knowledge and data from a range of scientific and social scientific disciplines.[132] How that integration occurs presents a series of intellectual and practical challenges. Not only may theory and data differ from discipline to discipline, but the activity of modelling has an iterative feedback to the different disciplines upon which it draws.[133] Focusing on modelling thus highlights that the physical and social sciences are not monolithic domains and the knowledge drawn on for regulatory decision-making comes from a range of different disciplinary sources.[134] Likewise, different models will be grounded in different disciplines. There is

131 Wagner and others (n 2).

132 J Rotmans and H Dowlatabadi, 'Integrated Assessment Modelling' in S Rayner and E Malone (eds), *Human Choice and Climate Change: Volume Three Tools for Policy Analysis* (Battelle Press, Columbus, OH 1998); H Nowotny and others *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty* (Polity Press, Cambridge 2001) 106; Pascual (n 99).

133 Rotmans and Dowlatabadi (n 132) 294.

134 J Kagan, *The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century* (CUP, Cambridge 2009).

no single modelling textbook or university course which will equip someone with the ability to understand all models.

The second aspect of interdisciplinary complexity concerns the fact that modelling is a distinct and highly technical discipline which must interact with other disciplines and contexts. The problem is that policy-makers and decision-makers need to engage with models, but it cannot be pretended that in doing so they are modelling experts who have in-depth knowledge of modelling as a discipline. Modelling is a highly specialised practice distinct from law and policy. The reluctance on the part of lawyers and policy-makers to engage with models is thus entirely understandable. Models may span the science/policy divide but it does not mean that it is easy for lawyers and policy-makers to become modelling experts. Models are a product of particular specialist bodies of knowledge and modelling is a discipline in its own right with its own vocabulary, concepts and internal debates. Thus, while it is common (and correct) to argue for modelling to be transparent,[135] the challenge in doing so should not be underestimated. It is not the case that modelling is a hidden practice, but instead that the language and techniques of modelling are opaque to non-modellers who lack the necessary background to understand modelling arcana.

The third type of interdisciplinary complexity which arises from this is one about accountability. There are some who have argued that interdisciplinary discourses lead to greater accountability,[136] but the reality is that holding decision-makers to account becomes far more difficult when they are drawing on a highly technical model. This is because it becomes far harder for a decision-maker or lawyer to evaluate the quality of the arguments when they are based on something that a lawyer and policy-maker finds difficult to understand. Models thus may regulate administrative power but their role in accountability processes is fraught. Indeed, when models do become the subject of legal and policy disputes, the ability of lawyers and policy-makers to assess the accountability of decisions based on a model becomes questionable.[137]

There are two important implications of recognising interdisciplinary complexity. The first is that while models are of relevance to lawyers and policy-makers it is not the case that they are easily understandable by those groups. Care and thought should be taken with how lawyers and policy-makers engage with these models. Indeed, the policy and legal landscape are littered with instances of where lawyers and policy-makers have engaged with models in completely inappropriate ways.[138]

135 NRC (n 3) 100–11.

136 M Strathern, *Commons and Borderlands: Working Papers on Interdisciplinarity, Accountability and the Flow of Knowledge* (Sean Kingston Publishing, Wantage 2004) 68–86.

137 *Downs* (n 36) [38].

138 For a discussion of this point see Shapiro (n 40); McGarity and Wagner (n 44).

Following on from this, it needs to be appreciated that lawyers and policy-makers need to develop some form of expertise in dealing with models. Clearly, it is not the same expertise as a modeller who is expected to directly contribute to modelling as a discipline. Rather, the expertise that lawyers and policy-makers need to develop is an expertise in interacting with modelling.[139] This is a form on interactional expertise which is '[e]xpertise in the *language* of a specialism in the absences of expertise in its *practice*'.[140]

The distinction between these two forms of expertise is difficult to draw and care should be taken with that distinction.[141] With that said, it is a useful distinction to draw because it clarifies the scope of interaction.[142] Clarifying that scope of interaction does not necessarily provide any simple answers—interactional expertise is not a straightforward concept and developing even linguistic expertise is difficult.[143]

By engaging with interdisciplinary complexity it is again seen that the science/policy divide looks increasingly problematic, albeit in a different way than discussed above. Interdisciplinary complexity arises from the fact that distinctions between policy and science do exist and thus there is effectively a divide. At the same time, however that divide does need to be bridged and crossed.

3.4 Evaluative Complexity

The final form of complexity that lawyers and policy-makers must consider is the most significant – evaluative complexity. This is the most significant because the primary concern of lawyers and policy-makers in dealing with a model is whether that model serves as a legitimate basis for a decision and, to evaluate that, there needs to be a focus on the quality of the model. Indeed, this was the fundamental focus of the NRC report *Models in Environmental Regulatory Decision-Making* and it dedicated significant consideration to the issue.[144] As with above, we do not attempt to solve the problems created by

139 The distinction between contributory and interactional expertise is taken from H Collins and R Evans, *Rethinking Expertise* (University of Chicago Press, Chicago 2007). See also H Collins and others, 'Trading Zones and Interactional Expertise' (2007) 38 Studies in History and Philosophy of Science 657.

140 Collins and Evans (n 139) 28.

141 S Jasanoff, 'Breaking the Waves in Science Studies: Comment on H.M. Collins and Robert Evans, "The Third Wave of Science Studies"' (2003) 33 Social Studies of Science 389; B Wynne, 'Seasick on the Third Wave? Subverting the Hegemony of Propositionalism: Response to Collins & Evans (2002)' (2003) 33 Social Studies of Science 401.

142 For a broader discussion of its use in environmental law see E Fisher and others 'Maturity and Methodology: Starting a Debate about Environmental Law Scholarship' (2009) 21 JEL 213 at 231–5.

143 And often problematic because the same word can mean different things in different disciplines. See Kagan (n 134) 5–11.

144 NRC (n 3) 104–69.

this form of complexity but cannot overstress the importance of recognising this as a complexity in its own right. Indeed, nearly all the policy and legal disputes seen above are disputes that raise issues to do with evaluative complexity because in them lawyers and policy-makers need to evaluate the quality of models which regulate decision-making.

Evaluative complexity largely arises due to the confluence of technical, institutional and interdisciplinary complexity. Technical complexity means that uncertainty is inherent in modelling and that modelling is malleable. In terms of evaluating models this means 'that while the rigor of a model can be established it is impossible to verify the truth of a model'.[145] Models can be evaluated for rigour but cannot be validated as true (although they can be invalidated for being false).[146] It is for this reason that the term 'model evaluation' is favoured over 'model validation'.[147] Yet, in focusing on the rigour of modelling it needs to be recognised that modelling is an inherently malleable exercise. Therefore, model evaluation cannot be about assessing whether a model adheres to a strict formula—at the same time, it is not the case that 'anything goes'.[148]

Again, one response to this problem has been to argue that a way of evaluating models is to determine their fitness for purpose.[149] As Morrison and Morgan note, a model is not assessed 'on its ability to accurately mirror a system, rather the legitimacy of each representation is a function of the model's performance in specific contexts.'[150] This would seem to offer a possible way of developing a framework for evaluating models but it needs to be understood this is not a purely functional and straightforward exercise but rather one that encounters institutional complexity. Whether a model is understood to be fit for purpose is not an objective or isolated question but will depend on what is understood to be legitimate public administration. Moreover, as seen above, the way in which models are conceptualised under the RI paradigm of public administration is wrong. Therefore there exists a danger that models will be judged against inappropriate yardsticks.

This problem is exacerbated by interdisciplinary complexity. Models do need to be evaluated by lawyers and policy-makers but they are not modelling experts. Thus, while models do enable decision-makers to base their decisions on information, the technical nature of such models can prevent the

145 Oreskes (n 107).
146 NRC (n 3) 104.
147 Oreskes (n 107); B Beck, 'Model Evaluation and Performance' in A El-Shaarawi and W Piegorsch (eds), *Encyclopedia of Environmetrics* (John Wiley & Sons, Chichester 2002).
148 P Feyerabend, *Against Method: Outline of an Anarchistic Theory of Knowledge* (3rd edn Verso, London 1993).
149 NRC (n 3) 3.
150 Morrison and Morgan (n 88) 28.

evaluation of both models and the information on which they are being based.[151] With that said, what is clear from above is that while the technical nature of models must be acknowledged, models are not simply scientific structures—they are interdisciplinary 'boundary objects' and 'infrastructures'[152]—and thus must be engaged with.[153]

Evaluative complexity does not end with the conflation of the forms of complexity already discussed however. Another aspect of it is the fact that regulatory actors will engage with models and utilise them to their own ends. The different forms of complexity described above can thus be manipulated for particular ideological or instrumental purposes.[154] This form of manipulation has been described by different commentators as 'manufacturing uncertainty'[155] and 'analytical opportunism'.[156] The typical practice that these labels refer to is where a regulatory actor, wishing to achieve a certain regulatory outcome, will argue that the scientific uncertainty inherent in models is a fundamental flaw which means that a model is not reliable.[157] This type of manipulation is complicated by interdisciplinary complexity in that it can be difficult to know whether such arguments have some merit. The important point to appreciate is that the issue of evaluating models also has a profoundly ideological and regulatory-outcome-driven dimension.[158] Again that is the reason why modelling has become the focus for legal and policy disputes.

We do not offer up any easy solutions to how lawyers and policy-makers should evaluate models – we do not pretend that the process of evaluation will be easy. This is particularly because lurking close to the issue of evaluative complexity are broader problems stemming from an overly simplistic understanding of science and policy.[159] What we do think is that it is essential that the issue of evaluative complexity is on the agenda for lawyers and policy-makers and that an important starting point is an appreciation of just

151 S Leigh Star and K Ruhleder, 'Steps Towards An Ecology of Infrastructure Design and Access for Large Information Spaces' (1996) 7 Information Systems Research 111, 111.
152 Pascual (n 93).
153 G Bowker and S Leigh Star, *Sorting Things Out: Classification and Its Consequences* (MIT Press, Cambridge 2000) 24, 34.
154 T McGarity and W Wagner, *Bending Science: How Special Interests Corrupt Public Health Research* (Harvard UP, Cambridge 2008); W Wagner, 'The Science Charade in Toxic Risk Regulation' (1995) 95 Columbia Law Review 1613.
155 D Michaels and C Monforton, 'Scientific Evidence in the Regulatory System: Manufacturing Uncertainty and the Demise of the Formal Regulatory System' (2005) 13 Journal of Law and Policy 17.
156 Fisher (n 1) 121–2.
157 W Freudenburg and others 'Scientific Uncertainty Argumentation Methods (SCAMs): Science and the Politics of Doubt' (2008) 78 Sociological Inquiry 2.
158 Wagner and others (n 2).
159 Fisher (n 1); Michaels (n 35).

how difficult an issue evaluation is. Thus, statements ensuring that models are 'transparent', and 'fit for purpose' should be treated less as solutions and more as the serious intellectual and practical challenges they are.[160]

4. Conclusions

Our argument in this article has been that models are not just a prevalent feature of environmental regulation but they are also relevant to what lawyers and policy-makers do and need to be engaged with critically. There are three important conclusions that we draw from our analysis.

First, models cannot be ignored or overlooked by lawyers or policy-makers. Models are not just the province of the scientific boffins and the techno-heads. Models frame how environmental issues are understood, they provide the basis and rationale for regulatory action, and they play a significant role in establishing the legitimacy of regulatory regimes. Indeed the increasing prevalence and institutionalisation of models in environmental regulation, as well as the fact that they are subject to disputes, points to their importance. Lawyers and policy-makers have no choice but to engage with them.

Second, that engagement must take a critical and sophisticated form. We have not set out in this article how that process of engagement should occur. In light of the complexities discussed above, such prescriptions would be unhelpful and counter-productive. One thing is clear however—the real issue for lawyers and policy-makers is how to properly evaluate the quality of models and that requires not only engagement with evaluative complexity but also technical, institutional and interdisciplinary complexity.

Third, the critical engagement with models cannot be seen in isolation but also requires lawyers and policy-makers to reflect more generally on the boundaries of their discipline. Much of the analysis in this article has argued for lawyers and policy-makers to broaden their field of intellectual vision. Models cannot be ignored just because they lie on the other side of a disciplinary divide. Likewise, lawyers in particular, need to engage with parts of the administrative process which they have not traditionally understood as within their domain. A critical engagement with models is not then just about learning a lot about models and their role in environmental regulation but also thinking more carefully about what lawyers and policy-makers do.

Thus, while in this article we have not dazzled, bamboozled or overwhelmed you with technical jargon or data, we have laid down a serious intellectual

160 Pascual (n 96) 2011; Beck (n 147). On the abuse of transparency see Michaels (n 35) 176–91.

challenge for lawyers and policy-makers. We have shown that models are prevalent and relevant and require the development of a broad critical agenda. What we have not done is provide any easy formulae or techniques for how policy-makers and lawyers should engage with models and we know that will frustrate many readers. As our analysis makes clear however, no such formulae or techniques exist.